02-27-08

Attorney Docket No. AM-8893 Y1

U.S. Express Mail No.: EB 998981463 US

### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

RE APPLICATION OF: Ki-Ho Baik et al.

§ GROUP ART UNIT: 1756

§ (In parent case)

SERIAL NO.: 10/817,140

§ EXAMINER: B.L. Raymond

RCE FILED: October 25, 2007

(In parent case)

FOR: METHOD OF IMPROVING THE UNIFORMITY OF

A PATTERNED RESIST ON A PHOTOMASK

Attorney Docket No.:

AM-8893 Y1

Date: February 25, 2008

### NOTICE OF FILED RESPONSE TO DECISION DISMISSING PETITION <u>TRANSMITTAL LETTER</u>

Mail Stop Amendment Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450

A Declaration of Prior Invention Under 37 CFR § 1.131 was submitted on October 25, 2007. Accompanying the Declaration was a Petition In Support of Declaration of Prior Invention Under 37 CFR § 1.131 for acceptance of the Declaration without signatures of two inventors who could not be located at that time.

The Petition was dismissed by Petitions Attorney Grant on January 3, 2008. Applicants' attorney has submitted a Response to Decision Dismissing Petition, which Response was filed at Mail Stop Petition on February 25, 2008. A copy of the Response to Decision Dismissing Petition and accompanying documentation is enclosed.

### **CERTIFICATE OF MAILING UNDER 37 CFR § 1.10**

I hereby certify that this paper is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 998981707 US in an envelope addressed to: Mail Stop Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L. Qhurch, Reg. No. 31,85

As a result of a second effort to obtain two missing signatures of the five inventors, applicants' attorney was able to obtain the signature of Inventor Homer Lem on the Declaration of Prior Invention Under 37 CFR § 1.131. The Declaration of Prior Invention Under 37 CFR § 1.131 with Homer Lems' signature is submitted herewith.

In the event that the Response to Decision Dismissing Petition filed February 25, 2008 is granted, the Examiner is hereby requested to accept the Declaration of Prior Invention Under 37 CFR § 1.131 by the inventors. The Examiner is then requested to withdraw the citation of Kirkpatrick (U.S. Patent Application 2006/0084229) in view of Itoh (U.S. Patent Application 2004/0058279) against the claims currently pending in the application.

Applicants do not believe that any fee is due in connection with the filing of this Notice of Filed Response to Decision Dismissing Petition. Applicants do not believe any fee is due in connection with the filing of the copy of the Declaration of Prior Invention executed by Inventor Homer Lem. However, in the event any fees are due, the Commissioner is hereby authorized to charge any additional fees which may be due, and to credit any overpayment to Deposit Account No. 50-1512 of Shirley L. Church, Esq. of San Diego, California, in the amount of such fee.

This transmittal letter is submitted in duplicate for accounting purposes.

Respectfully Submitted,

Date: February 25, 2008

Shirley L. Church Registration No. 31,858 Attorney for Applicants

wiley L. Church

(858) 587-6633

Correspondence Address: Customer No. 60767 Shirley L. Church, Esq. P.O. Box 81146 San Diego, CA 92138 tarney Docket No. AM-8893

U.S. Express Mail No.: EB 796042834 US

### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

RE APPLICATION OF: Ki-Ho Baik et al.

§ GROUP ART UNIT: 1756

SERIAL NO.: 10/817,140

FEB 25 2008

**EXAMINER: B.L. Raymond** 

FILED: April 2, 2004

FOR: METHOD OF IMPROVING THE UNIFORMITY OF §Attorney Docket No.:

A PATTERNED RESIST ON A PHOTOMASK

AM-8893

Date: February 25, 2008

### **DECLARATION OF PRIOR INVENTION UNDER 37 CFR § 1.131**

**Mail Stop Petition** Hon. Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450

Sir:

This Declaration is to be combined with the Declaration Under 37 CFR § 1.131 which was filed in response accompanies Response "B", which is in response to the Office Action mailed July 25, 2007.

Ki-Ho Baik, Mark A. Mueller, Stephen Osborne, Robert Dean, and Homer Lem are joint inventors of the invention claimed in U.S. Patent Application Serial No. 10/817,140. I, Homer Lem, declare that said invention was conceived and reduced to practice by the above-named inventors prior to January 6, 2004, which is the filing date of U.S. Patent Application Serial No. 10/752,885, which was published on December 30, 2004, as U.S. Publication No. 2004/0266113.

### **CERTIFICATE OF MAILING UNDER 37 CFR 1.10**

I hereby certify that this paper and any documents said to accompany this paper are being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 450583747 US in an envelope addressed to: Mail Stop AF, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

In support of our Declaration, attached is a copy of the Invention Alert which preceded the present patent application. This Invention Alert was prepared by us and sent electronically to the docketing department of Applied Materials, Inc. on 11/21/2003. Subsequently, the Invention Alert was returned to us for signature, and signatures were obtained between December 17 and December 18, 2003. The signatures were witnessed on December 18, 2003, a Docket No. of 8893 was assigned, and the Invention Alert was scheduled to be sent out to an attorney for preparation of a patent application on that date.

Portions of the Invention Alert which pertain to conclusory dates of invention have been dedacted to protect the rights of the inventors.

We, the undersigned, each declare that all statements made herein are of his own knowledge true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Sec. 1001 of Title 18 of the United States Code, and that such willful false statements and the like may jeopardize the validity of the application or any patent issued thereon.

)		
	Ki-Ho Baik, Co-inventor	
)		
	Mark A. Mueller, Co-inventor	
)		
•	Stephen Osborne, Co-inventor	
	Robert Dean, Co-inventor	
Jan. 22, 2008	Home Lem	
	Homer Lem, Co-inventor	

U.S. Express Mail No.: EB 998981707 US

### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

X RE APPLICATION OF: Ki-Ho Baik et al.

§ GROUP ART UNIT: 1756

(In parent case)

SERIAL NO.: 10/817,140

FEB 25 2008

EXAMINER: B.L. Raymond

RCE FILED: October 25, 2007

(In parent case)

FOR: METHOD OF IMPROVING THE UNIFORMITY OF

A PATTERNED RESIST ON A PHOTOMASK

§ Attorney Docket No.:

AM-8893 Y1

Date: February 25, 2008

## RESPONSE TO DECISION ON PETITION IN SUPPORT OF DECLARATION OF PRIOR INVENTION UNDER 37 CFR § 1.131 <u>TRANSMITTAL LETTER</u>

Mail Stop PETITION Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450

Transmitted herewith is applicants' Response to Decision Dismissing Petition, including Exhibit "A" - Declaration of Line Gauthier Under MPEP 409.03(d); Exhibit "B" - internet search results; Exhibit "C" - letter and accompanying documents sent to Inventor Stephen Osborne requesting signature; Exhibit "D" - statement from U.S. Post Office Delivery personnel; and a copy of the Declaration of Prior Invention Under 37 CFR § 1.131 with Inventor Homer Lem's signature. For reference purposes, applicants have also enclosed a copy of the Petition in

### **CERTIFICATE OF MAILING UNDER 37 CFR § 1.10**

I hereby certify that this paper is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 998981707 US in an envelope addressed to: Mail Stop Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L. Charch, Reg. No. 31,858

U.S. Express Mail No.: EB 998981707 US

Support of Declaration of Prior Invention Under 37 CFR§ 1.131 including a copy of the original Invention Alert signed by all five of the inventors.

Applicants do not believe that any additional fee is due in connection with the filing of this Response to Decision Dismissing Petition. However, in the event any fees are due, the Commissioner is hereby authorized to charge any additional fees which may be due, and to credit any overpayment to Deposit Account No. <u>50-1512</u> of Shirley L. Church, Esq. of San Diego, California, in the amount of such fee.

This transmittal letter is submitted in duplicate for accounting purposes.

Respectfully Submitted,

Date: February 25, 2008

Shirley L. Church

Registration No. 31,858 Attorney for Applicants

(858) 587-6633

Correspondence Address: Shirley L. Church, Esq. P.O. Box 81146 San Diego, CA 92138 Attorney Docket No. AM-8893 Y1

U.S. Express Mail No.: EB 998981707 US

### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

RE APPLICATION OF: Ki-Ho Baik et al.

§ GROUP ART UNIT: 1756

(In parent case)

SERIAL NO.: 10/817,140

EXAMINER: B.L. Raymond

RCE FILED: October 25, 2007

(In parent case)

FOR: METHOD OF IMPROVING THE UNIFORMITY OF

A PATTERNED RESIST ON A PHOTOMASK

§ Attorney Docket No.: AM-8893 Y1

Date: February 25, 2008

### **RESPONSE TO DECISION DISMISSING PETITION MAILED JANUARY 3, 2008**

**Mail Stop PETITION Commissioner for Patents** P.O. Box 1450 Alexandria, VA 22313-1450

Sir:

- This Response to Decision Dismissing Petition is in reply to the Decision on Petition 1. mailed January 3, 2008.
- This Response is made to obtain acceptance of the Petition In Support of Declaration of 2. Prior Invention Under 37 CFR § 1.131. The Petition accompanied Response "B", which was made in reply to the Office Action mailed July 25, 2007. Petition Attorney Grant informed applicants' attorney in her Decision On Petition, that the Petition was dismissed because the

**CERTIFICATE OF MAILING UNDER 37 CFR 1.10** 

I hereby certify that this paper and any documents said to accompany this paper are being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 998981707 US in an envelope addressed to: Mail Stop PETITION, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L, Phurch, Reg. No.31,858

Petition Examiner concluded that Petitioner had failed to show adequate proof that a diligent effort was made to reach or locate inventors Osborne and Lem.

- 3. Applicants' attorney, with the exercise of diligent effort, has located inventor Homer Lem who has signed the Declaration Of Prior Invention Under 37 CFR § 1.131. Applicants are enclosing a copy of the Declaration executed by inventor Lem.
- 4. Applicants have now found four of the five inventors, each of whom has signed the Declaration Of Prior Invention Under 37 CFR § 1.131.
- 5. On January 17, 2008, an assistant of applicant's attorney, Line Gauthier, searched for information regarding the fifth inventor, Stephen Osborne. Inventor Osborne no longer works for Applied Materials, Inc. and left without giving a forwarding address to his employer. Applicants used the Internet search engines Google and www.peoplelookup.com and found numerous persons named Stephen Osborne scattered across the United States. Applicants telephoned the Phone Operator asking for phone numbers relating to the name Stephen Osborne in the city where Inventor Osborne was last known to reside, Hayward, California, and its vicinity. The Phone Operator offered three phone numbers, which applicants dialed. All three phone numbers were wrong numbers.
- 6. Further, on January 17, 2008, applicants sent a letter to Inventor Osborne at his last known address, via Express Mail, requesting a delivery signature, and including a request letter, the Declaration of Prior Invention Under 37 CFR § 1.131, the Invention Alert Form, a copy of the application as filed, and a self-addressed, stamped envelope.
- 7. On February 6, 2008, the U.S. Postal Service returned the unopened package to applicants' attorney stating that Stephen Osborne had moved leaving no forwarding address.

- 8. On February 12, 2008, we extended our research outside of the Hayward area and requested assistance from the Phone Operator to find a Stephen P. Osborne in Woodland Hills, California; Middleton, Wisconsin; Santa Monica, California; and Santa Clara, California. There were no such listings.
- 9. Applicants are enclosing a copy of the internet search results (Exhibit "B"), a copy of the letter to Inventor Osborne and accompanying documents (Exhibit "C"), and a copy of the returned envelope with the U.S. Postal Service statement that Inventor Osborne moved without leaving a forwarding address (Exhibit "D").
- 10. Applicants believe that the enclosed documents are adequate proof that a diligent effort was made to locate Inventor Osborne, who left his place of employment and residence without leaving a forwarding address either to his employer or with the U.S. Postal Services. A Statement Of Facts that fully describes the exact facts which applicants are relying upon to establish that a diligent effort was made to locate Inventor Osborne is also enclosed (Exhibit "A)". The Statement is signed by attorney's assistant, Line Gauthier, who performed the research and prepared the letter sent to Inventor Osborne, and who, thus, has first hand knowledge of the facts recited therein.
- 11. Applicants have obtained the signatures of four of the five inventors on the Declaration of Prior Invention Under 37 CFR § 1.131; combined with this is the fact that all five of the inventors executed an Invention Alert describing the invention prior to the date at issue (and a copy of that Invention Alert has been submitted as part of the Declaration of Prior Invention). The Office of Petitions is respectfully requested to grant the Petition In Support of Declaration of Prior Invention Under 37 CFR § 1.131 in Application Serial No. 10/817,140. This Petition requests the Declaration of Prior Invention Under 37 CFR § 1.131 be accepted without the signature of one inventor (Stephen Osborne). Granting of the Petition is necessary so that

inventors' Declaration of Prior Invention will be accepted by Examiner B.L. Raymond in pending Application Serial No. 10/817,140.

12. This Petition is accompanied by the fee required under 37 CFR § 1.17(f).

Date: February 25, 2008

Shirley L. Church

Registration No. 31,858 Attorney for Applicants

Respectfully submitted,

(858) 587-6633

Correspondence Address: Customer No. 60767 Shirley L. Church, Esq. P.O. Box 81146 San Diego, California 92138

### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION OF: Ki-Ho Baik, et al.

§ GROUP ART UNIT: 1763

SERIAL NO.: 10/817,140

§ EXAMINER: B.L. Raymond

FILED: April 2, 2004

FOR: METHOD OF IMPROVING THE UNIFORMITY

**ATTORNEY DOCKET NO.:** 

OF A PATTERNED RESIST ON A PHOTOMASK

AM-8893 Y1

Date: February 25, 2008

# DECLARATION OF LINE GAUTHIER UNDER MPEP 409.03(d) EXHIBIT "A"

Mail Stop PETITION
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

This Declaration under MPEP 409.03(d) accompanies a response to the Decision Dismissing Petition mailed January 3, 2008.

I, Line Gauthier, an assistant to Shirley L. Church, Esq., having firsthand knowledge of the facts recited herein, declare that the statements below are the exact facts showing the diligent effort I exercised to locate Inventor Stephen P. Osborne, an inventor of the invention claimed in U.S. Patent Application Serial No. 10/817,140, who no longer works for Applied Materials, Inc. and who has left no forwarding address with his last known employer, Applied Materials, Inc. nor with the U.S. Postal Services at his last known address.

### **CERTIFICATE OF MAILING UNDER 37 CFR § 1.10**

I hereby certify that this paper and any documents said to accompany this paper are being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 998981707 US in an envelope addressed to: Mail Stop Patent Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L. Church, Reg. No.31.858

- 1. Inventor Osborne's last known address is 1128 "D" Street, Hayward, CA 94541.
- On January 17, 2008, I searched the name Stephen Osborne in the Google search engine and found www.peoplelookup.com, which listed a large number of Stephen P. Osborne in several cities, in several states, thus rendering the search difficult. A copy of the search result is enclosed (Exhibit "B").
- I called the Phone Operator and asked if a phone number was available for a Stephen P. Osborne in Hayward or near Hayward, California. The operator had only one listed number for Stephen P. Osborne in Hayward and two more in Santa Clara and Valencia. I called the number in Hayward but was told this was the wrong Stephen Osborne.
- 4. I called the other two phone numbers in Santa Clara and Valencia and was told they were wrong numbers.
- In order to extend the scope of my search, I called the Phone Operator for assistance in finding listings for Stephen P. Osborne in Canyon Country, California; Woodland Hills, California; Middleton, Wisconsin; Santa Monica, California; and Santa Clara, California. There were no such listings.
- 6. On January 17, 2008, I sent a letter to Mr. Osborne at his last known address, via Express Mail, requesting a signature at delivery. Copies of the letter, the Declaration of Prior Invention Under 37 CFR § 1.131, the Invention Alert Form and application as filed are enclosed, self-addressed, stamped return envelope are enclosed (Exhibit "C").
- 7. On February 6, 2008, the United States Post Service returned the package to us indicating that Stephen Osborne had moved without leaving a forwarding address. A copy of the returned envelope showing the statement from the U.S. Post Service delivery person is also enclosed (Exhibit "D).

- 8. On February 12, 2008, I extended my research outside of the Hayward area and requested assistance from the Phone Operator to find a Stephen P. Osborne in Woodland Hills, California; Middleton, Wisconsin; Santa Monica, California; and Santa Clara, California. There were no such listings.
- 9. I have no telephone number for Stephen P. Osborne and no current address after having made the above-described effort to locate Stephen P. Osborne.

Date:

Line Gauthier

Attorney Docket No. AM-8893 Y1

U.S. Express Mail No.: EB 998981707 US

FEB 25 1008

IN EAPPLICATION OF: Ki-Ho Baik, et al.

\$ GROUP ART UNIT: 1763

\$ EXAMINER: B.L. Raymond

FILED: April 2, 2004

FOR: METHOD OF IMPROVING THE
UNIFORMITY OF A PATTERNED RESIST ON A

\$ AM-8893 Y1

**PHOTOMASK** 

### EXHIBIT "B"

### WWW.PEOPLELOOKUP.COM SEARCH RESULTS

PEOPLES LOOKUPO			• .			Login   My Account Customer Service
People Search R	Reverse Phone	Background Check	eck	Cell Ph	Cell Phone ID	Other Services
PEOPLE LOOKUP RESULTS 41 People found that match Stephen Osborne	RESULTS Stephen Osborne				:	Search Again >>
Click on the Name or View Details link for more info.  V = Available Information	tails link for mor	e info.			ိပ်	See Details on All 41 People!
STATE OF THE STATE	ÀĞË	PREVIOUS CITIES	ров	PHONE	Abbress	RELATIVES
STEPHEN P OSBORNE  1 Get More Info	9A 7U 7U TU	PAHRUMP, NV YUMA, AZ TUCSON, AZ	7	<b>,</b>	7	STEVE P OSBORNE VIRGINIA C OSBORNE MARK W OSBORNE WILLIAM G OSBORNE STEVEN J OSBORNE
STEPHEN PHILIP OSBORNE 2 Get More Info	HA CA CA MI MI SA	HAYWARD, CA CANYON COUNTRY, CA WOODLAND HILLS, CA MIDDLETON, WI SANTA MONICA, CA	7	<b>&gt;</b>	7	CYNTHIA CROSBY OSBORNE
STEPHEN P OSBORNE 3 Get More Info	34 00	OCALA, FL	>	>	>	STEVEN P OSBORNE
STEPHEN PAUL OSBORNE 4 Get More Info	49 GA FO	GARLAND, TX FORNEY, TX	>	>	>	THERESA OSBORNE AMIE OSBORNE BLAKE OSBORNE WUT T OSBORNE ALET OYCE OSBORNE JOYCE CHANEY OSBORNE JERRY WILLIAM OSBORNE
STEPHEN P OSBORNE S Get More Info	34 00	OCALA, FL	>	7	>	STEVEN P OSBORNE JAIME OSBORNE
STEPHEN P OSBORNE 6Get More Info	49 MI	MILAN, TN MEDINA, TN	>	7	7	
STEPHEN P OSBORNE 7 Get More Info	51 BO SA	CHULA VISTA, CA BONITA, CA SAN DIEGO, CA	7	<b>\</b>	>	BERIT OSBORNE MAXINE L'OSBORNE DIANE APRIL OSBORNE LINDA N OSBORNE
STEPHEN PATRICK OSBORNE   Get More Info	£	DELAND, FL.	>	7	7	STEVE LEE OSBORNE SARA L OSBORNE
STEPHEN P OSBORNE 9 Get More Info	85 PIT	PITTSBURGH, PA	•	<b>.</b>	>	MARY J OSBORNE STEVE OSBORNE
STEPHEN P OSBORNE 10 Get More Info.	BO NE SAI 40 TAI OLL	BOCA RATON, FL NEWARK VALLEY, NY SAINT PETERSBURG, FL TAMPA, FL OLDSMAR, FL PINELLAS PARK, FL	>	>	7	STEVEN P OSBORNE
NAME .	AGE PR	PREVIOUS CITIES	DOB	PHONE	ADDRESS	RELATIVES

2/12/2008 3:27 PM

RYAN OSBORNE DELFINA OSBORNE CARY F OSBORNE	D OSBORNE STEVE OSBORNE		SARA L OSBORNE	THERESA M OSBORNE		JOHN OSBORNE BETTY OSBORNE JANET L OSBORNE SHARON MAE OSBORNE ELIZABETH OSBORNE WILLIAM JOHN OSBORNE	CAROLYN H OSBORNE DANIEL CAROLYN OSBORNE	STEVEN P OSBORNE		RELATIVES IRENE C OSBORNE VOUNE O OSBORNE	MARY J OSBORNE JAMES W OSBORNE	STEVE P OSBORNE	JOHN S OSBORNE	
7	7	7	7	7	>	>	7	7	>	ADDRESS	>	>	7	>
7	>	<b>,</b>	>	7	7	<b>,</b>	>	•		PHONE.	,	•		
>	7	>	>	7	ı	•	>	>	>	BOG >		>	7	>
NEWHALL, CA	VALENCIA, CA	OCALA, FL	DELAND, FL	MESQUITE, TX	витіє, мт	ВИТТЕ, МТ	RODMAN, NY	OCALA, FL	OCALA, FL	PREVIOUS CITIES. OCALA, FL	PITTSBURGH, PA	LYNN, MA	PHOENIX, AZ	OCALA, FL
85	28	34	51	49	•	•	23	34	34	AGE 34	85	36	28	34
STEPHEN PATRICK OSBORNE 11 [Get More Info	STEPHEN P OSBORNE  12 Get More Info	STEPHEN P OSBORNE  13  Get More Info	STEPHEN P OSBORNE 14 Get More Info	STEPHEN P OSBORNE 15 Get More Info	STEPHEN P OSBORNE  16 Get More, Info	STEPHEN P OSBORNE 17 Get More Info.	STEPHEN P OSBORNE 18 Get More Info	STEPHEN P OSBORNE  19 Get More Info		STEPHEN P OSBORNE 21 Get More Info	STEPHEN P OSBORNE 22 Get More Info	STEPHEN P OSBORNE 23 Get More Info	STEPHEN P OSBORNE 24 Get, More Info	STEPHEN P OSBORNE 25 Get More Info

STEPHEN P OSBORNE

			•	RELATIVES						STEVE P OSBORNE				RELATIVES
7	7 -	7	>	Abdress	>	>	7	7	7	7	7	7	7	✓ ADDRESS:
•		7	ı	- PHONE			I			>		,		PHONE
\'	>	•	•	2	<b>4</b>	,	1	•	•	•	7			<b>7</b>
CANYON COUNTRY, CA 🖊	HOUSTON, TX	NORMAN, OK	DENVER, CO	SAN DIEGO, CA		SANTA CLARA, CA	CHULA VISTA, CA	витте, мт	витте, мт	YUMA, AZ	CHULA VISTA, CA	PINELLAS PARK, FL	РАСОІМА, СА	IRWIN, PA PREVIOUS CITIES
89	22		46	51 AGE			,	•	•	•	. 51	•	1	31 AGE
26 Get More Info	STEPHEN P OSBORNE 27 Get More Info	STEPHEN P OSBORNE 28 Get More Info	STEPHEN P OSBORNE 29 Get More Info	STEPHEN P OSBORNE 30 Get More Info		STEPHEN P OSBORNE 32 Get More Info	STEPHEN P OSBORNE  33  Get More Info	STEPHEN P OSBORNE 34 Get More Info	STEPHEN P OSBORNE 35 Get More Info	STEPHEN P OSBORNE 36 Get More Info	STEPHEN P. OSBORNE 37 Get More, Info	STEPHEN P OSBORNE 38 Get, More, Info	39 Get More Info	STEPHEN P OSBORNE  40  GGE MOTE INFO

2/12/2008 3:27 PM

STEPHEN P OSBORNE

41 Get More Info

- SANTA MONICA, CA

RELATED PEOPLE SEARCHES

STEFAN OSBORNE

STEPHAN OSBORNE

STEVAN OSBORNE

STEVE OSBORNE

STEVEN OSBORNE

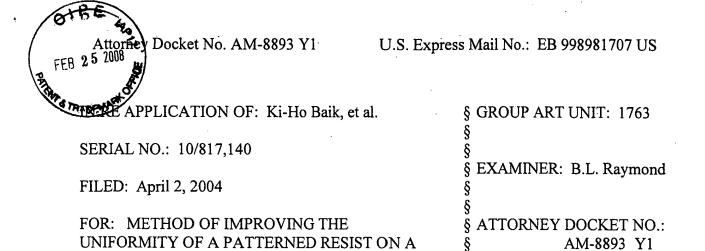
STEVIE OSBORNE

S OSBORNE

Help | Contact Us | FAOs | Terms & Conditions
A Naveen Jain Company
Copyright © 2003-2008, PeopleLookup

A HACKER
ISTID 12-103

2/12/2008 3:27 PM



**PHOTOMASK** 

### **EXHIBIT "C"**

### **LETTER SENT TO INVENTOR OSBORNE**

Flat Rate O or Weight

Int'l Alpha Country Code

Acceptance Emp. Initials

and Day

D PM O AM Year

> Military Noos

Scheduled Time of Delivery

COD Fee

] 3 PM

Total Postage & Fees \$

PAYMENT BY ACCOUNT Express Mail Corporate Acct. No.

Federal Agency Acct. No. or Postal Service Acct. No.

Day

FROM: (PLEASE PRINT)

PHONE (

TO: (PLEASE PRINT)

PHONE ( 858)

587-6633

SZ0

visit www.usps.com

气星弱多

FOR PICKUP OR TRACKING

AM-8893 Y1

Hayward, CA

94541

San Diego, CA

P.O.

Box 81146

Shirley L. Church,

Esq.

Stephen Osborne 1228 D Street

Call 1-800-222-1811

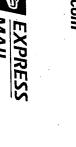
ะแแกลกิจเล่น กาแแกล - ลก เก กจะกาแกกลกิจเล่นแกล

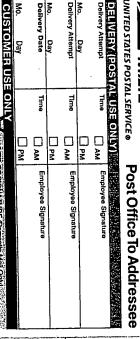
# STATES POSTAL SERVICE

Vlailing Envelope

Visit us at usps.com







ORIGIN (POSTAL! SERVICE USE ONLY)
PO ZIP Code Dalivery

Next 2nd 2nd Del. Day

Scheduled Date of Delivery

Return Receipt Fee

**4EB24096** 

Mailing Label	A TRADEMAN



)76, or 2976A) s declarations internationally



pursue an innovative vision of is awarded to products that Cradle to Cradle Certification This USPS® packaging has been of waste. that eliminates the concept ecologically-intelligent design

certified for its material content, characteristics. recyclability, and manufacturing

Please recycle

ZIP + 4 (U.S. ADDRESSES ONLY. DO NOT USE FOR FOREIGN POSTAL CODES.

FOR INTERNATIONAL DESTINATIONS, WRITE COUNTRY NAME BELOW

ဖ

2

ω

Φ

+

g





Shirley L. Church, Esq. 600 FAX (858) 587-6613

Email Address: Shirley\_Church@slcpatlaw.com

Physical Office Address: 6540 Lusk Boulevard, Suite C- 274 San Diego, CA 92121 Mailing Address: P.O. Box 81146 San Diego, CA 92138-1146

January 18, 2008

### Via Express Mail

Mr. Stephen Osborne 1228 D Street Hayward, CA 94541

RE:

U.S. Patent Application No.: 10/817,140

or: "Method of Improving the Uniformity of a Patterned Resist on Photomask"

Filed: April 2, 2004

Our Ref. No.: AM-8893 Y1

Dear Mr. Osborne:

We are filing a Request for Continued Examination of the above-referenced application of which you are an inventor. We are enclosing a copy of a *Declaration of Prior Invention Under 37 CFR § 1.131* for your signature. We need your signature to proceed with the application.

Also enclosed are a copy of the patent application as filed and a copy of the invention alert showing critical dates for your reference. A self-addressed envelope is included for the return of the signed Declaration of Prior Invention

As you may know, inventors must <u>sign and date</u> the Declaration to be accepted by the PTO. Also, all hand-written changes must be initialed by the inventor making such changes. Please return the signed and dated Declaration to us by <u>February 1, 2008</u> so that we may file the document with the U.S. Patent Office in a timely manner.

We thank you so much for your assistance in this matter. Please do not hesitate to contact us if you have any questions or comments.

With my best regards,

Shirley L. Church, Esq.

SLC:lsg Enclosures

cc: Maureen Walstra, Patent Administrato (via email only)
patent office@amat.com(via email only)

# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\		
IN RE APPLICATION OF THE HARDIN et al.	§ GROUP A	RT UNIT: 1756
SERIAL NO.: 10/817,140	§ § 8 FYAMIN	ER: B.L. Raymond
FILED: April 2, 2004	§ EZZAMIN § 8	ER. B.L. Raymond
FOR: METHOD OF IMPROVING THE UNIFORM A PATTERNED RESIST ON A PHOTOMA		Docket No.: 393
	Date:	, 2008
DECLARATION OF PRIOR INVEN	TION UNDER 37 C	FR § 1.131
Mail Stop AF Hon. Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450		
Sir:		
This Declaration under 37 CFR § 1.131 accomp	panies Response "B",	which is in response to the
Office Action mailed July 25, 2007.		
We, Ki-Ho Baik, Mark A. Mueller, Stephen	Osborne, Robert Dea	n, and Homer Lem hereby
declare that we are joint inventors of the invention cl	aimed in U.S. Patent	Application Serial No.
10/817,140. We further declare that said invention	was conceived and re	duced to practice by us prior
to January 6, 2004, which is the filing date of U.S. Pa	atent Application Ser	al No. 10/752,885, which
was published on December 30, 2004, as U.S. Public		113.
CERTIFICATE OF MAILING In hereby certify that this paper and any documents said to a sthe U.S. Postal Service on the date shown below with suffice B 450583747 US in an envelope addressed to : Mail Stop Alexandria, VA 22313-1450.	UNDER 37 CFR 1.10 accompany this paper a cient postage as U.S. E	XPRESS MAIL NO.
Date:, 2008	Chirloy I Church De-	1- 24 050
	Shirley L. Church, Reg. I	0.3 I,030

In support of our Declaration, attached is a copy of the Invention Alert which preceded the present patent application. This Invention Alert was prepared by us and sent electronically to the docketing department of Applied Materials, Inc. on 11/21/2003. Subsequently, the Invention Alert was returned to us for signature, and signatures were obtained between December 17 and December 18, 2003. The signatures were witnessed on December 18, 2003, a Docket No. of 8893 was assigned, and the Invention Alert was scheduled to be sent out to an attorney for preparation of a patent application on that date.

Portions of the Invention Alert which pertain to conclusory dates of invention have been dedacted to protect the rights of the inventors.

We, the undersigned, each declare that all statements made herein are of his own knowledge true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Sec. 1001 of Title 18 of the United States Code, and that such willful false statements and the like may jeopardize the validity of the application or any patent issued thereon.

)	·	Ki-Ho Baik, Co-inventor
	·	Mark A. Mueller, Co-inventor
	, 2008	Stephen Osborne, Co-inventor
	······································	Robert Dean, Co-inventor
	<u>.</u>	Homer Lem, Co-inventor



ALERT NO: 881

# INVENTION ALERT FORM

TO: Gaile Balley M/S 2061/Extension 32724

Date: 11/21/2003

CIRCLE ONLY ONE FROM TOP ROW(REQUIRED FIELD):-

MASK/ETEC

	RT																		
	MMCS/	APC	MMCS/	Controller	C.F.C	Straterys			PDC-DSI	3396									
HDPCVID CONDUCTIVE MDR 0281 1077	PARAMETRIC	1755	ORJON/CON	2471		ORIGNIPAR	2471									-			
HDPCVD 9281	BCVD	0166	LOW K	2445		ELK	2445											Dual Dam	
FBT 3037	MDR/ DSI	3047											-						
ATD APD FBT 3037	CDSEM		WF			DRSEM				OEM CEM		בַּ			EBI				
ATD 1301													-						
AKT	Tur	193			٠.					İ									
COPPER		ALUMINUM 2492		LINER	7667		Copper	Plating(ECV)	2492										COPPER
CORB	0793	EPS 2590		DF 2492															
CPS	0700	SMO/ GAS	1649	SMO/ PUMP	1691		BPIC	241	•	SCAI PEI			CONSTRUM	21.99		ECOM			
AL	1881	SILICON		DIELECTRIC	0521		DIELECTRIC		1611	CONDINCTOR	CONDOCTOR.	1894	CHAMBER	TECH	0894	CORB TECH	1245		
CMP	1399												•					2.00	The second second
WCVD	2492	TIVI'IN 2492		ALD															
EPV	SUBSTRATE	0X0		LPCVD			GCM	1166	cace		WEICLEAN	3365	PMU	3169		DIMER	1164	2000	and September of the second section 2.

I. Title of Invention (please print clearly): Vacuum Treatment for Improvement of Uniformity of Patterned Resist on a Photomask and Wafer

2. Inventors-Names only-(please print clearly and provide complete information at Section 9.) Ki-Ho Baik, Mark Mueller, Steve Osborne, Robert Deau, Homer Lem



Please use separate attachments for any answers that dorn't fit on the form, especially for questions 3-8. If the answer to a question is "NONE", please write "NONE" wather than leaving the answer blank.

3. Earliest dates and model names of all Applied products incorporating the invention which have been offered for sale or are expected to be offered for sale:

Mebes eXara, electron beam photomask writer,

RSB, electron beam photomask writer,

Tetral, photomask etcher.

Tetra2, photomask etcher,

4. If the invention has been demonstrated or described to persons other than Applied employees, for each disclosure please provide the earliest date, name of company, a brief description of what was disclosed and the purpose of the disclosure. Attach a copy of any related non-disclosure agreements:

NOT described outside Applied Materials, not yet disclosed.

5. If future disclosures like those in Question #4 are expected to occur within the next 12 months, please provide the anticipated date, type of information to be disclosed, and purpose of the disclosure:

NONE []

This invention would be most useful for ETEC to meet its technical specifications and commitments at IBM, where an RSB is being evaluated and compared to a competing product. Therefore it would be in Applied Materials' business interests to disclose this invention to IBM as soon as possible, in order to improve the ETEC-RSB product performance and gain a competitive advantage.

Preliminary data shows an improvement in resist local CD uniformity as a result of vacuum treatment. CD uniformity improvement in resist is between zero and 1 nm 3sigma, which is significant.

This invention is expected to be of significant interest to the photomask user community. Thus publication, after patent filing protection of IP, would serve Applied Materials' interests in advertising lithographic patterning capabilities.

Describe any other known designs or processes, whether actually implemented or merely proposed in a publication, which could be considered similar to your invention or which constitute the state-of-the-art improved upon by your invention: If described in a publication, attach a copy of same or provide a citation.

No known publications describe anything similar to this invention.

A broad search on the US Patent Office website (USPTO.com) scanning for the phrase "resist AND vacuum AND (semiconductor OR lithography OR photomask)" in claims turned up no previous patent which has any similarity to the invention proposed here. There are no reported applications of vacuum processing which claim or report what we are listing below as a novel and non-obvious feature.

The state-of-the-art electron beam photomask processing sequence is summarized:

1. Photomask is coated with resist, post-exposure baked (PAB), and exposed (electron beam or INVALET.DOC 12/17/03/GB

laser used for creating a pattern onto the pho-tomask resist).

- 2. The photomask is post-exposure baked (PEE) and developed, which removes the unpatterned resist from the plate.
- 3. The photomask is then etched, whereby the resist pattern is transferred into an underlying chrome layer. Additional etching may be required for phase-shift masks (PSM).

- 7. List each feature of the invention which you consider novel and non-obvious. Describe the advantages of each novel feature in comparison with the state-of-the-art approaches which are most similar to your invention:

  Novel and Non-Obvious Features:
  - 1) Use of a post-develop, pre-etch vacuum processing step to reduce variation in critical dimensions on photomasks. The advantage of such a processing step is of enormous benefit to photomask manufacturers. By reducing variation in critical dimensions, the quality of the photomask is improved.

    State of the art: No specific vacuum treatment of photomask. The photomask is simply developed, air exposed (and possibly measured in a CD-SEM to get resist CD information), and then the chrome is etched.
  - 2) Use of vacuum to alter the composition and dimensions of resist features on a photomask. By applying a vacuum to a photomask (or wafer) for about 20 minutes, water vapor and solvent are desorbed by the surface of the resist. This may enable surface tension (or other mechanisms not yet studied in complete detail) to minimize roughness on the sidewall of a resist feature, which reduces line edge roughness (LER) and also reduces CD variation. Vacuum processing affects the mean CD by only a few nanometers.

State of the art: One commonly applied means of altering resist dimensions on a photomask (or wafer) is the use of a "descum" oxygen plasma step. This basically burns away a fixed amount of resist, which unifortunately reduces the resist dimensions by at least 30nm, but also may also help to smoothen line edges. Descum treatment is not applicable to small feature lithography, since the step consumes a significant amount of lateral resist.

3) Application of vacuum treatment to reduce Line Edge Roughness (LER) on resist lines on a photomask (patterned by either electron beaun or laser).

State of the art: Descum (see #3 above).

- Application of vacuum to a photomask plate in a photomask etching chamber in which chamber walls and dome are heated, allowing the resist on the photomask to warm to a temperature between 30 degrees C and 55 degrees C, which enables the desorption from the surface of the resist of water vapor, solvents, and materials absorbed onto the surface from the develop process step and other previous steps. In particular, the Applied Materials Tetra etching system is used for this vacuum treatment. Photomasks are placed into a chamber for 20 minutes of vacuum time, where the 55 degree chamber wall and 70 degree dome radiate heat onto the photomask plate. Longer times do not provide any improvement in desorption. The "curve" of resist change is observed to flatten out at 20 minutes.
- 5) Application of a vacuum treatment to a photomask (or wafer) after electron beam exposure (or laser or other methods of resist exposure) to reduce critical dimension variation.

### INVENTION ALERT FORM

Preliminary data from delayed removal of a photomask from the RSB electron beam writer has shown that CD uniformity may be slightly improved. A nixte-hour delay time was utilized in this preliminary work. Delayed removal places the photomask in vacuum for a longer period, prior to air exposure and immediate Post-Exposure Bake. It is possible to perform this vacuum treatment in a Tetra (Applied Materials photomask etcher) chamber, where the vacuum treatment does not impact the RSB throughput. It is also possible to perform the vacuum treatment in other vacuum chambers.

Generalization of #1 through 5 to include was fers and other substrates. General application to wafers can improve the quality of lithography in the patterning of wafers. Specifically, this can be applied to all wafer lithographic processes where critical dimension control is required, for all wavelengths of light utilized in wafer lithographic (G-line, i-line, KrF, ArF, 157) plus other methods used for patterning resist on wafers, such as e-beam, FIB, X-ray, and EUV. Line edge roughness is reduced, and critical dimension control is improved.

8. Describe the invention, preferably with reference to attached drawings:

The invention consists of an additional processing step in the standard "state of the art" sequence described above in Part 6. This is specifically a vacuum applied to the photomask between Step 2 and Step 3 (as noted above in Part 6). Proper timing of the vacuum allows for desorption of materials from the resist surface. Such desorption is found to slightly decrease the thickness of the resist layer. In addition, a slight shrinkage of pattern dimension is observed in the lateral (photomask plane) directions. Moreover, our data shows an improvement in Local CD Uniformity, in which crosses of a given fixed size are printed within a 1mm square, and then measured. Variations in local CD Uniformity can be attributed to a) various electron beam fluctuations during resist patterning and b) process-related line-edge roughness. The ETEC process has succeeded in drastically reducing the latter by creating a proprietary resist and fine-tunking all of the resist-related processing parameters. However, we believe at this time that vacuum processing is capable of further reduction in line-edge roughness, resulting in reduced Local CD Uniformity.



Two types of vacuum treatment are described above in the previous section. Vacuum treatment can be applied to a photomask immediately after exposure and before PEB (Post Exposure Bake). This enables acids within the resist to diffuse in such a way as to improve contrast and to reduce line edge roughness.

Another vacuum treatment is applied to the photomask after develop. In this second vacuum treatment, water vapor and solvents are desorbed. from the surface of the patterned resist. In this case, the surface includes sidewalls and the top resist surface. By desorbing the volatile components, the resist loses material and that part of resist close to the surface is in tension. This surface tension may allow for the "pulling together" of the surface which may smooth out sidewall roughness. Since the tension does not apply to the bulk of the resist (deeper than within a few nanometers of the surface), lines and other features are not distorted.

ATTACH ADDITIONAL SHEETS TO DESCRIBE: INVENTION AS NEEDED

Provide the following information for EACH inventor\*\* REQUIRED FIELDS:

Inventor # 1: Legal Name:	Ki-Ho Baik	Employee # 89446 Mail Stop 14100
_	510-780-3771	Fax No.: 510-780-2121
Job Title:	Sr. Director	
Citizenship	S. Kores	
_	1533 Whispering Oaks V	Nay. Pleasanton, CA 94566
Manager:	Damon Cole	Title: Program Director
Div. Manager	Ronen Ben Tzion	Title: General Manager
Product Group:	ETEC	Dept.#: 0667
Inventor #2: Legal Name:	Mark A. Mueller	Employee # 11522 Mail Stop 14100
1	510-780-3898	Fax No.: 510-780-2121
Job Title:	Member of Technical Staf	f
Citizenship:	USA	
Complete Hon	ne Address: 1272 Bellair W	ev. Menio Park, CA 94025
Manager:	Ki-Ho Baik	Title: Sr. Director
Div. Manager	Ronen Ben Tzion	Title: General Manager
Product Group	:ETEC	Cost Center #:0667
Inventor #3: Legal Name:	Stephen Osborne	Employee # 86669 Mail Stop 14100
Work Phone	510-887-3398	Fax No.: 510-780-2121
Job Title:	Process Development	Engineer IV
Citizenship:	USA	
Home Address	s: 1228 D Street, Havw	ard, CA 94541
Manager:	Ki-Ho Baik	Title: Sr. Director
Div. Manager	Ronen Ben Tzion	Title: General Manager
Product Grou	p: ETEC	D <del>spt</del> #:0667

### INVENTION ALERT FORM

Inventor #4: Legal Name:	Robert Dean		Employee #	81426 Mail Stop <u>14100</u>
Work Phone	510-887-3444	_Fax.N.o:_	510-780	-2121
Job Title:	Member of Technical Staff	<del></del>		
Citizenship:	USA	<del>`</del>	·	
Home Address:	5306 Greenridge Rd., Castr	o Valley, C	CA 94582	
Manager	Ki-Ho Baik	· 	Title:	Sr. Director
Div. Manager	Ronen Ben Tzion		Title:	General Manager
Product Group:	ETEC		Dept #: _	0667

### INVENTION ALERT FORM

Inventor #5: Legal Name:	Homer Lem	Exn	ployee # <u>8</u>	1483	Mail Stop _1	4100	
_	510-887-3664	Fax No.:	510-780	0-2121			
Job Title:	Principal Engineer	<del></del>	<del></del>			<del></del>	. •
Citizenship:	USA		<u> </u>				
Home Address	1247 Gretel Lane, Mount	ain Visw. C.A	94040		· · · · · · · · · · · · · · · · · · ·	<del></del>	
Manager:	Ki-Ho Baik		Title: _	Sr. Ma	nager	<u>-</u>	
Div. Manager	Ronen Ben Tzion		Title: _	Gener	al Manager		
Product Group:	ETEC		Dept #:	0667			
Inventor							
Legal Name:		E	mployee #		Mail Stop	· · · · · ·	
Work Phone	Fm	No:			<del></del>	<del></del>	
Job Title:				-	······································	·	
Citizenship:		- <u>-</u>	<del></del>				. •
Home Address:		·	·				
Manager		· · · · · · · · · · · · · · · · · · ·	Title:		·	·····	
Div. Manager			Title: _			<del></del>	,
Product Group	:			Dept#:_	•		_

10. Signature, date and <u>PRINTED</u> name of each inventor plus two witnesses who have read and understood this Invention Alert form:

Inventors:		1.0 0 1.1 00
MARK MUELLER	18/7/03	Mark Muello
		Signature
Printed Name  Robert Dean  Printed Name	12/17/03	
Printed Name	Date '	Signature
K: HO BATIC	14/A/03	Buch
Printed Name	Date	Signature
Homer LEM Printed Name	12/18/03	House Lan
Printed Name	Date	Signature
STEIZIEIN OSIBURA	<u> </u>	Signatures
Printed Name	Date	Signatur
Printed Name	Date	Signature
Witness:		$\Omega = \Omega = 0$
DAMON M. COLE	12/18/03	& James H. Col
Printed Name	Date	Signature
Allen R. Cook	12/18/03	White look
Printed Name	Daté	Signature

Return to:

Gaile Bailey

Mail Stop:

2061

Fax No.:.:

986-3090

Extension:

563-2724

U.S. Express M. No.: ER452506884US

Docket No. AM-8893 FEB 2 5 2008

[0001]

# F IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK

3 [0002] 1. Field of the Invention

[0003] In general, the present invention relates to a method of producing a photomask (reticle) for use in the semiconductor industry. In particular, the invention pertains to a method for improving the critical dimension (CD) uniformity of a pattern in a photoresist which is used to transfer the pattern to a reticle.

### [0004] 2. <u>Brief Description of the Background Art</u>

Photoresists are used in microlithographic processes to produce patterned features required for device functioning in miniaturized electronic components, such as in the fabrication of semiconductor device structures. The miniaturized electronic device structure patterns are typically created using blanket radiation through a photomask to produce a pattern in a layer of photoresist material present on a semiconductor structure. There are instances, for specialized devices, where a pattern is directly written into a photoresist present on the semiconductor structure; however, due to the slow production speed of the direct write process, this is not commonly done.

[0006] A photomask or reticle which is used to enable rapid semiconductor device processing typically includes a thin layer of a radiation-blocking material (which is often a

[0006] A photomask or reticle which is used to enable rapid semiconductor device processing typically includes a thin layer of a radiation-blocking material (which is often a metal-containing material, such as a chrome-containing, molybdenum-containing, or tungsten-containing layer, for example) deposited on a glass or quartz plate. The thin layer of radiation-blocking material is patterned to contain a "hard copy" of the pattern to be recreated on the photoresist or photoresist / hard mask layer overlying a semiconductor structure. The patterning of the radiation-blocking layer of a reticle may be carried out using a number of different techniques. Due to the dimensional requirements of today's semiconductor structures, the pattern is typically generated using a direct write laser or e-beam to create a latent image in a photoresist for subsequent transfer to the radiation-

U.S. Express M. No.: ER452506884US

blocking layer.

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

The reticle manufacturing process generally includes the following steps, when [0007] the initial substrate used to form the reticle is a silicon oxide-containing base layer having a layer of a metal-containing (typically chrome) mask material applied thereover: An inorganic antireflective coating (ARC) or an organic ARC, or a combination of inorganic and organic ARC layers, may be applied over the surface of the chrome mask material. A photoresist layer is then applied over the antireflective coating. The photoresist is typically an organic material which is dissolved in a solvent. The solution of photoresist is typically spin coated onto the surface of the photomask fabrication structure. Some of the solvent is removed during the spin coating operation. Residual solvent is subsequently removed by another means, typically by baking the fabrication structure, including the photoresist layer. This step is commonly referred to as a "post-apply bake" or PAB. The photoresist is then exposed to radiation (imaged), to produce a pattern in the photoresist layer, typically by a direct write process when the pattern includes dimensions which are less than about 0.4  $\mu m$ or less. After exposure, the substrate including the photoresist layer is baked again. The second baking is typically referred to as a "post-exposure bake" or PEB. The photoresist is then developed, either using a dry process or a wet process, to create the pattern having openings through the photoresist layer thickness. Once the photoresist is "patterned" so that the pattern openings extend through the photoresist layer to the upper surface of an ARC layer, or to a surface beneath an ARC layer, the pattern in the patterned photoresist is transferred through the chrome-based mask layer and any remaining layers overlying the chrome layer, for example, typically by dry etching. As described above, preparation of a photomask / reticle is a complicated process involving a number of interrelated steps which affect the critical dimensions of a pattern produced in the reticle and the uniformity of the pattern critical dimensions across the surface area of the reticle. Various efforts have been made within the industry to improve the reliability of manufacturing processes by improving individual process steps; however, when a production process involves a number of interrelated process steps, alteration of an 1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

individual process step may have an unexpected result on other interrelated process steps. [0009] Commonly owned U.S. Patent No. 6,703,169, to Scott Fuller et al., issued March 9, 2004, and entitled "Method of Preparing Optically Imaged High Performance Photomasks", discloses a state-of-the-art method of fabricating a photomask using optical radiation in the form of a direct write continuous wave laser. The claimed method comprises a series of steps including: applying an organic antireflection coating over a metal-containing layer; applying a chemically-amplified positive tone or negative tone DUV photoresist over the organic antireflection coating, to provide a photoresist-coated photomask substrate; post-apply baking the DUV photoresist over a temperature ranging from about 105°C to about 115°C; exposing a surface of the DUV photoresist to radiation from the direct write continuous wave laser, to provide a patterned photoresist across the photomask substrate; and post-exposure baking the DUV photoresist over a temperature ranging from about 70°C to about 90°C. The post-apply bake process provides increased stability period for the photoresist-coated photomask substrate, where there is less than a 5 nm change in a 400 nm latent image critical dimension after a 6-hour time period. A combination of the post-apply bake process and the post-exposure bake process results in a uniform critical dimension of the patterned photoresist across the photomask substrate, where, for a 132-mm x 132-mm active area, a critical dimension uniformity is ≤ 10 nm at 400 nm. The disclosure of U.S. Patent No. 6,703,169 is hereby incorporated by reference in its entirety. Commonly owned, co-pending U.S. Application Serial No. 10/768,919, of [0010] Christopher Dennis Bencher et al., filed January 30, 2004, and entitled "Reticle Fabrication Using a Removable Hard Mask", discloses a method of fabricating a reticle which provides improved critical dimension uniformity during fabrication of a reticle by minimizing the problem known as "photoresist pull-back", which commonly occurs during etching of a chrome (or other radiation-blocking layer) on a reticle substrate. According to the method disclosed by Bencher et al., pattern transfer to the radiation-blocking layer of the reticle substrate essentially depends upon transfer from a hard mask rather than from a photoresist.

2

3

4

5

6

7

8

9

10

11

.12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

In one embodiment, a hard mask material having anti-reflective properties is left on the surface of the chrome after etching of the chrome. Since the hard mask surface faces the surface of a photoresist on the semiconductor substrate which is patterned using the reticle, the presence of the proper anti-reflective properties in the hard mask can be used to reduce the amount of bounce-back of reflected radiation which occurs during blanket radiation imaging of the semiconductor photoresist through the reticle. In another embodiment, where a wet etch is used during fabrication of the reticle, the hard mask material (whether having anti-reflective properties or not) is removed to prevent contamination during the wet etch process. In this embodiment, when a plasma etchant used to remove the hard mask would also etch the reticle base substrate (which is typically quartz), a protective layer is applied to fill at least a portion of patterned openings through the chrome during removal of the hard mask. This prevents etching of the quartz at the bottom of the pattern openings during removal of the hard mask. The disclosure of U.S. Application Serial No. 10/768,919 is hereby incorporated by reference in its entirety. [0011] As device dimensions become even smaller, further improvements in critical dimension uniformity of photomasks are needed. One commonly used means of improving photomask dimensional uniformity is by improving the dimensions of the patterned photoresist used to transfer the pattern to the photomask. The patterned photomask may be "descummed" using an oxygen plasma step, in which surface defects are removed from the photoresist pattern. Exposure to the oxygen plasma basically burns away a fixed amount of resist, which may help to smooth pattern line edges. Unfortunately, however, the descum oxygen plasma step typically reduces the resist dimensions by about 20 - 30 nm, making the descum process inapplicable to very small feature lithography. [0012] It is readily apparent that it would be highly desirable to have a method of making a photomask where the uniformity of pattern critical dimensions is maintained across the entire surface of the photomask, even for features smaller than about 100 nm. To provide an improved photomask, it would be very advantageous to provide an improved patterned photoresist which can be used to transfer the pattern directly to the photomask, or to transfer

the pattern to a hard mask which is subsequently used to pattern the photomask.

SUMMARY OF THE INVENTION [0013] 2 3 [0014] We have discovered that application of a vacuum to a pattern irradiated (imaged) photoresist prior to development of the photoresist provides an improvement in critical 4 5 dimension and uniformity in the developed photoresist. This improvement is translated into an improvement in the patterned photomask produced using the photoresist. 6 7 Typically, the application of vacuum is carried out prior to a post-exposure bake 8 of the kind which is commonly performed on an imaged photoresist prior to development. Exposure of the photoresist on the photomask substrate to vacuum is performed for a period 9 of time sufficient to allow the imaged pattern critical dimensions to reach equilibrium across 10 the photoresist. The vacuum treatment process allows reaction by-product, water vapor, and 11 12 solvents, for example, to desorb from the surface of the resist, improving critical dimension 13 uniformity across the surface of the photoresist on the photomask substrate. 14 [0016] Typically, exposure of the pattern-imaged photoresist to vacuum is performed at 15 a substrate temperature within the range of about 18°C to about 60°C (more typically, within the range of about 18°C to about 40°C), for a period of time within the range of 16 17 about 10 minutes to about 70 hours (more typically, within the range of about 20 minutes 18 to about 12 hours), at a process chamber pressure ranging from about 5 x 10<sup>-6</sup> mTorr to about 5 mTorr. The pressure within the processing chamber during the vacuum treatment 19 process may be limited by the capability of the particular apparatus in which the vacuum 20 21 treatment process is performed. For example, when the vacuum treatment process is 22 performed in an Applied Materials' e-beam direct-write apparatus 23 following the pattern writing process, the process chamber pressure during the vacuum treatment process is typically about 1 x 10<sup>-5</sup> mTorr. When the vacuum treatment process is 24 25 performed in an Applied Materials' TETRATM etch system, the process chamber pressure 26 during the vacuum treatment process may vary between about mTorr to about 27 mTorr, and was typically in the range of about 0.5 mTorr to about 1 mTorr during the

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

experimentation described herein.

The time period required for pattern critical dimensions to reach equilibrium across the photoresist will depend upon the photoresist layer composition, and a combination of the temperature of the substrate / photoresist during the vacuum treatment process and the pressure (vacuum) applied. The minimal time period required for vacuum treatment of the photoresist on the photomask substrate will be the time period which provides no substantial change in pattern critical dimensions upon continued exposure of the irradiated photoresist to the vacuum. Typically, the higher the temperature, the less time is required for pattern critical [0018] dimensions to reach equilibrium. However, the temperature is limited by the general stability of the photoresist material, which will depend on the particular photoresist material used. Also, typically the lower the pressure in the process chamber, the less time is required for vacuum treatment at a given temperature; however, the pressure used must ensure that deformation of the pattern does not occur and that the integrity of the photoresist is preserved. The amount of time required will also depend upon the condition of the photoresist prior to the vacuum treatment process, which will depend upon the type of photoresist used, the solvents in the photoresist, and the length of time of the post-apply bake (PAB) process. With minimal experimentation, one skilled in the art will be able to integrate the vacuum treatment step into an existing process for photomask production. We have also discovered that exposure of the patterned (developed) photoresist [0019] to vacuum after development results in an improvement in the line edge roughness of pattern openings that have been formed through the photoresist layer thickness. This second vacuum treatment process is typically performed at a substrate temperature within the range of about 20°C to about 60°C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5 x 10<sup>-6</sup> mTorr to about 5 mTorr, where the time period is a function of the combination of temperature and pressure. In this second vacuum treatment, water vapor and solvents absorbed during the development process are desorbed from surfaces of the patterned resist, including the sidewalls and top

. 2

resist surface. During desorption of the volatile components, the portion of the resist which is close to the surface is placed in tension. It is theorized, but not intended as a limitation, that this surface tension may allow for the "pulling together" of the surface, which may smooth out sidewall roughness. Since the bulk of the resist (deeper than within a few nanometers of the surface) is not in tension, lines and other features are not distorted.

[0020] The vacuum treatment processes of the invention work well whether the photoresist on the photomask substrate has been exposed to electron beam (e-beam) or optical radiation. Vacuum processing of photomask substrates according to the method of the invention typically improves the mean CD of the patterned photoresist by reducing the variation from the intended CD by about 3 n.m or more, and by improving the uniformity (3-sigma) across a substrate surface by about 3 - 5 nm.

## [0021] BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Figure 1A shows a schematic cross-sectional view of a typical embodiment of a beginning structure 100 of a stack of materials used in the production of a photomask or reticle, when the pattern is transferred from the photoresist to the radiation-blocking layer of the mask without the use of a hard mask. The stack from bottom to top includes a substrate 102, which is typically selected from quartz, fluorinated quartz, borosilicate glass, or soda lime glass; a radiation-blocking layer 104, which is typically a metal-containing layer selected from a chromium, molybdernum silicide, or tungsten-containing layer, or combinations thereof (in the examples described herein, the radiation-blocking layer is essentially chrome); an inorganic ARC layer 105; an organic ARC layer 106; and a photoresist layer 108.

[0023] Figure 1B shows the Figure 1A structure 100 after development of the photoresist layer 108 to create a pattern of lines and spaces in the photoresist layer 108.

U.S. Express Ma. No.: ER452506884US

[0024] Figure 2 is a graph 200 showing a global cross 1 x CD uniformity (in nm) following vacuum treatment of the imaged photoresist prior to development, when the substrates were vacuum treated in a MEBES<sup>TM</sup> QUADRA<sup>TM</sup> imaging system ("RSB Vacuum") or were vacuum treated in an Applied Materials' TETRA<sup>TM</sup> etch chamber ("Tetra Vacuum"), compared with the global CD uniformity for substrates which received no

vacuum treatment following exposure of the photoresist to radiation ("No Vacuum").

[0025] Figure 3 is a graph 300 showing the decrease in developed photoresist thickness 302 as a function of time under vacuum 304, for photomask substrates which were vacuum treated in accordance with the present invention. The substrates were vacuum treated in an Applied Materials' TETRA<sup>TM</sup> etch chamber, at a temperature of approximately 45°C and a process chamber pressure of approximately 0.5 mTorr.

[0026] Figure 4 is a graph 400 showing local CD uniformity (in nm) before and after vacuum treatment of the developed photoresist. The substrates were vacuum treated in an Applied Materials' TETRA<sup>TM</sup> etch chamber for a period of 20 minutes, at a temperature of approximately 30°C and a process chamber pressure of approximately 1 mTorr.

### [0027] <u>DETAILED DESCRIPTION OF THE INVENTION</u>

[0028] We have discovered a method of improving the patterning of a layer of photoresist which has been applied over a photomask substrate, The present method results in improved critical dimension uniformity of the developed photoresist. In general, the method comprises the steps of: a) post-apply baking the photoresist; b) exposing the photoresist to imaging radiation (typically direct-write radiation); c) exposing the imaged photoresist to a vacuum for a period of time sufficient to allow pattern critical dimensions to equilibrate across the photoresist, at a process chamber pressure ranging from about 5 x 10<sup>-6</sup> mTorr to about 5 mTorr (typically, at a temperature ranging from about 20°C to about 60°C, and for a time period ranging from about 10 minutes to about 70 hours);

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

d) post-exposure baking the imaged photoresist; and e) developing the imaged photoresist to create a pattern having openings through the photoresist layer thickness.

[0029] The method may further comprise the additional step f) of exposing the developed photoresist to a vacuum subsequent to step e), at a substrate temperature within the range of about 20°C to about 60°C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5 x 10<sup>-6</sup> mTorr to about 5 mTorr. This second vacuum exposure step has been shown to improve the line edge roughness of pattern openings that have been formed through the photoresist layer thickness. [0030] As a preface to the detailed description presented below, it should be noted that, as used in this specification and the appended claims, the singular forms "a", "an", and "the" include plural referents, unless the context clearly dictates otherwise.

# [0031] I. <u>METHOD OF PATTERNING A PHOTORESIST ON A PHOTOMASK</u> <u>SUBSTRATE</u>

[0032] All methods of patterning a photomask substrate may benefit from application of the present method. The method is particularly useful for DUV optical or e-beam patterning of a photomask when a chemically amplified photoresist is used to transfer the pattern to the photomask. The present Examples are for a REAP<sup>TM</sup> 200 chemically amplified photoresist (available from Tokyo Ohka Kogyo Co., Ltd. (TOK), Kawasaki, Japan), which is useful with both e-beam radiation and 248 nm optical radiation. However, the scope of the invention is not intended to be limited to this family of chemically amplified photoresists. [0033] Figure 1A shows one embodiment of a starting structure 100 used in the fabrication of example photomasks for experimental purposes herein. In this Example, starting structure 100 was a stack of layers (not shown to scale) which included, from top to bottom, a 3000 Å thick layer 108 of a chemically amplified photoresist, REAPTM 200 (available from TOK, Kawasaki, Japan); a 500 Å thick layer 106 of an organic ARC identified as XLT-BARC (available from Brewer Science, Inc., Rolla, MO); a 300 Å thick layer 105 of chromium oxynitride inorganic ARC; a 400 Å thick layer 104 of chrome mask

U.S. Express M. No.: ER452506884US

1 material; and a silicon oxide-containing substrate 102. 2 The starting structure 100 shown in Figure 1A can be formed using conventional 3 deposition techniques known in the art of semiconductor manufacture. In particular, the 4 photoresist layer 108 is typically applied to the surface of the organic ARC layer 106 using 5 spin-on coating techniques. Some of the solvent or dispersion medium is removed during the spin coating operation. 6 7 [0035] Photoresist compositions of the kind suitable for use in the present method include: REAPTM 200 and EN24 (both available from TOK, Kawasaki, Japan); NEB 22 8 9 (available from Sumitomo Chemical Co., Ltd., Tokyo, Japan); and FEP 171 and FEN 270 10 (both available from Fuji-Hunt Electronics Company, Tokyo, Japan), by way of example 11 and not by way of limitation. After application of the photoresist layer, applicants performed a post-apply bake 12 [0036] 13 (PAB) process to remove residual solvent or dispersion medium. The post-apply bake 14 process is typically performed at a temperature within the range of about 70°C to about 15 150°C, for a time period of about 4 minutes to about 30 minutes. A particularly useful post-16 apply bake process is described in detail in U.S. Patent No. 6,703,169, to Fuller et al., the 17 disclosure of which is incorporated by reference in its entirety. 18 After post-apply bake, the photoresist was exposed to radiation (imaged), to [0037] 19 produce a latent pattern in the photoresist layer, typically by a direct write process when the 20 pattern includes dimensions which are less than about 0.4  $\mu$ m. In the example embodiment, the minimum pattern dimension was about 60 nm. In the exposure process, the integrated 21 22 circuit patterns were direct written onto the unpatterned photoresist 108 coated on a mask 23 blank which included organic ARC layer 106, inorganic ARC layer 105, chrome-containing 24 layer 104, and quartz layer 102 (described above). In a different embodiment, a hard mask 25 (not shown) may be present between the photoresist 108 and the radiation-blocking layer 26 104. 27 [8800] The vacuum treatment process of the invention works well whether imaging of 28 the photoresist is by e-beam radiation or by optical radiation. In the examples described

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

. 18

19

20

21

22

23

24

25

26

27

28

herein, imaging of the photoresist was performed in a MEBES™ QUADRA™ electron beam mask patterning system (available from ETEC Systems, Inc., an Applied Materials company, with Applied Materials, Inc., having offices in Santa Clara, CA). Other imaging systems which can be used to practice the method described herein include, without limitation, the MEBES<sup>TM</sup> eXara<sup>TM</sup> electron beam mask patterning system, and the ALTA<sup>TM</sup> 3900 and ALTA™ 4300 laser beam mask patterning systems (all available from ETEC Systems, Inc.). After imaging of the photoresist on the photomask substrate, the imaged [0039] photoresist was treated with a vacuum for a period of time sufficient to allow pattern critical dimensions to reach equilibrium across a given photoresist layer. The time period required for latent, imaged pattern critical dimensions to reach equilibrium across the photoresist will depend upon a combination of the temperature of the substrate during the vacuum treatment process and the pressure (vacuum) applied. A fter exposure of the imaged photoresist on the photomask substrate to vacuum for an optimum time period, no substantial change in pattern critical dimensions will occur upon continued exposure of the imaged photoresist to vacuum. Typically, the higher the temperature, the less time is required for imaged pattern [0040] critical dimensions to reach equilibrium. However, the temperature is limited by the general stability of the photoresist material, which will depend on the particular photoresist material used. Also, typically the lower the pressure in the process chamber, the less time is required at a given temperature; however, the pressure used must ensure that deformation of the pattern does not occur and that the integrity of the photoresist is preserved. The amount of time required will also depend upon the condition of the photoresist prior to the vacuum treatment process, which will depend upon the type of photoresist used, the solvents in the photoresist, and the length of time of the post-apply bake (PAB) process. With minimal experimentation, one skilled in the art will be able to determine the amount of time required based on the particular apparatus that s/he is using and the particular process conditions under which that apparatus typically operates.

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

Vacuum treatment of photomask substrates in accordance with the methods of the [0041] invention can be performed in any suitable semiconductor processing apparatus which is capable of maintaining a process chamber pressure within the range of about 5 x 10-6 mTorr to about 5 mTorr. For example, an imaged photomask substrate may be vacuum treated in the exposure tool used for direct-write pattern irradiation of the photoresist. Alternatively, vacuum treatment of the imaged photomask substrates can be performed in other available equipment, for example, and not by way of limitation, in an Applied Materials' TETRATM photomask etch system. By moving the photomask substrates to a different chamber for vacuum treatment following imaging, exposure tool throughput is not affected. Typically, exposure of the imaged photoresist on the photomask substrate to [0042] vacuum is performed at a substrate temperature within the range of about 18°C to about 60°C (more typically, within the range of about 18°C to about 40°C. Heating of the imaged resist on the photomask substrate to a temperature within the range of about 30°C to about 60°C, and at a pressure ranging from about 0.1 mTorr to about 5 mTorr provides a substantial improvement in imaged resist pattern uniformity after a treatment. Figure 2 is a graph 200 showing global cross 1 x CD uniformity 202 (in nm) [0043] following vacuum treatment of the imaged photoresist prior to development, where the substrates were vacuum treated in the MEBES™ QUADRA™ imaging system ("RSB Vacuum") 204 or were vacuum treated in arr Applied Materials' TETRATM etch chamber ("Tetra Vacuum") 206, compared with the global CD uniformity for substrates which received no vacuum treatment following exposure of the photoresist to radiation ("No Vacuum") 208. The RSB Vacuum substrates were vacuum treated in the pattern writing apparatus for a period of 5 - 9 hours at approximately 21 - 22°C), at a process chamber pressure of approximately 1 x 10<sup>-5</sup> mTorr. The Tetra Vacuum substrates were vacuum treated in a TETRATM etcher for a period of 30 minutes at a temperature of approximately 30°C, at a process chamber pressure of approximately 1 mTorr The substrates which received no vacuum treatment were maintained at approximately 21 - 22°C.

1	[0044] After vacuum treatment, the photoresist was baked again. The second baking step		
2 ·	is typically referred to as a "post-exposure bake" or PEB. Chemical reaction takes place		
- 3	between the time the pattern is written by irradiation upon the photoresist and the PEB, but		
4	after the PEB, the latent image is essentially fixed within the photoresist. The amount of		
5	time and the temperature of the substrate (i.e., the time / temperature profile) depends on the		
6	photoresist, and one skilled in the art can determine what this should be in view of the		
7	photoresist manufacturer's recommendations.		
8	[0045] The post-exposure bake process is typically performed at a temperature within the		
9	range of about 70°C to about 150°C, for a time period of about 4 minutes to about		
10	30 minutes. A particularly useful post-exposure bake process is described in detail in U.S.		
11	Patent No. 6,703,169, to Scott Fuller et al., the disclosure of which is incorporated by		
12	reference in its entirety.		
13	[0046] After post-exposure bake, the photoresist is developed, either using a dry process		
14	or a wet process, to create the pattern having openings through the photoresist layer		
15	thickness. The photoresist in the present instance was developed using a puddle or spray		
16	develop process with a TMAH (2.38 weight % or 1.91 weight %) developer.		
17	[0047] We have also discovered that exposure of the patterned (developed) photoresist		
18	to vacuum after development results in an improvement in the line edge roughness of pattern		
19	openings that have been formed through the photoresist layer thickness. Accordingly, after		
20	development of the photoresist, the method of the invention may further comprise an		
21	optional step of exposing the photoresist to a vacuum at a substrate temperature within the		
22	range of about 20°C to about 60°C for a period of time within the range of about 10 minutes		
23	to about 60 minutes, at a process chamber pressure ranging from about 5 x 10-6 mTom to		
24	about 5 mTorr.		
25	[0048] In this second vacuum treatment, water vapor and solvents absorbed during the		
26	development process are desorbed from surfaces of the patterned resist, including the		
27	sidewalls and top resist surface. During desorption of the volatile components, the portion		
28	of the resist which is close to the surface is placed in tension. It is theorized, but not		

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

intended as a limitation, that this surface tension may allow for the "pulling together" of the surface, which may smooth out sidewall roughness. Since the bulk of the resist (deeper than within a few nanometers of the surface) is not in tension, lines and other features are not distorted. [0049] Proper timing of the vacuum treatment process allows for desorption of water vapor, solvents, and other by-products of previous processing steps from the surface of the resist, and also enables acids within the resist to diffuse in such a way as to reduce line edge roughness. Desorption of materials from the resist was found to slightly decrease the thickness of the photoresist layer. In addition, a slight shrinkage of pattern dimension was observed in the lateral (photomask plane) directions. Overall, vacuum processing of photomask substrates according to the method of the invention typically improves the mean CD of the patterned photoresist by reducing the variation of the intended CD by approximately 3 nm or more, and by improving the uniformity (3 sigma) across the wafer by about 3 - 5 nm. Our data also show an improvement in local CD uniformity. Figure 3 is a graph 300 showing the decrease in photoresist thickness 302 for a developed photoresist as a function of time under vacuum 304 for photomask substrates which were vacuum treated in accordance with the present invention. The "curve" 306 of resist change is observed to "flatten out" (i.e., reach equilibrium) after about 20 minutes of vacuum treatment, after which no substantial change in pattern critical dimensions was observed upon continued exposure of the irraged photoresist to vacuum. The substrates were vacuum treated in an Applied Materials' TETRATM etch chamber for a period of 20 minutes, at a temperature of approximately 45°C, and a process chamber pressure of approximately 0.5 mTorr. The data presented graphically in Figure 3 is for the REAP™ 200 photoresist. Data were also obtained for the EN24 photoresist (available from TOK, Kawasaki, Japan) and FEP 171 photoresist (available from Fuji-Hunt Electronics Company, Tokyo, Japan), under the same processing conditions described above for the REAP<sup>TM</sup> 200 photoresist. These data are presented in Table One, below.

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

[0052] <u>Table One. Decrease in Photoresist Thickness Following Post-Exposure</u>

<u>Vacuum Treatment</u>

Photoresist	Decrease in Photoresist Thickness (Å)	
REAP™ 200	20	
EN24	23	
FEP 171	17	

Figure 4 is a graph 400 showing loc al CD uniformity 402 (in nm) before ("PreVac [0053] CDU") and after ("PostVac CDU") vacuum treatment of the developed photoresist. The substrates were vacuum treated in an Applied Materials' TETRATM etch chamber for 20 minutes, at a temperature of approximately 30°C and a process chamber pressure of approximately 1 mTorr. Local CD variations for the y direction pre-vacuum treatment 404 and post-vacuum treatment 406 are shown for a first sample ("Sample # 1"). Local CD variations for the y direction pre-vacuum treatment 408 and post-vacuum treatment 410, are also shown for a second sample ("Sample # 2"). The two photomask substrate samples had different line-and-space patterns, which would explain the variation in CD uniformity between the two samples. The data shown in Figure 4 are for a REAPTM photoresist (available from TOK, Kawasaki, Japan). In addition to their use in the preparation of photomasks, the vacuum treatment processes described herein can be used to improve the quality of lithography in the patterning of semiconductor wafers. The vacuum treatment processes described herein can be applied to all wafer lithographic processes where critical dimension control is required, for all wavelengths of light utilized in wafer optical and e-beam lithography (G-line, i-line, KrF, ArF, 257 nm, for example, and not by way of limitation), plus other methods used for patterning resist on wafers, such as EUV. Line edge roughness is reduced, and critical dimension control is improved.

2

3

5

Figure 1B shows a schematic cross-sectional view of the patterned photoresist [0055] layer 108 (prior to transfer of the pattern through underlying organic ARC layer 106, inorganic ARC layer 105, and chrome-containing layer 104), where the pattern was lines 107 and spaces 111, where the line width was about 30 nm to about 3  $\mu$ m and the spacing between lines was about 30 nm to about 3  $\mu$ m. Once the photoresist has been developed and "patterned", so that the pattern 6 [0056] openings extend through the photoresist layer to the upper surface of an ARC layer, or to a 7 surface beneath an ARC layer, subsequent processing steps are typically performed in order 8 to transfer the pattern in the patterned photoresist through the chrome-based mask layer and 9 any remaining layers overlying the chrome layer. These subsequent processing steps are 10 summarized below and are also described in detail in U.S. Patent No. 6,703,169, to Scott 11 Fuller et al., which is incorporated by reference herein in its entirety. The mask fabrication 12 13 process transforms the latent image created by the exposure of the photoresist into a 14 permanent chrome image on the quartz substrate. The pattern in the photoresist is typically transferred to the underlying photomask 15 [0057] structure using a dry etch process, such as a plasma etching process. The chrome oxynitride 16 (inorganic ARC) / chrome mask layer etch is typically performed using a plasma generated 17 from a chlorine / oxygen / helium gas mixture. Typically, higher oxygen concentrations and 18 lower pressures cause higher mean-to-target deviation and lower selectivities, while favoring 19 20 better CD uniformity control. Plasma etch systems such as the TETRATM etch system (available from Applied Materials, Inc., of Santa Clara, CA) may be used to provide 21 excellent results. However, one skilled in the art will be able to optimize the process for 22 other plasma etch apparatus. 23 Typically, the chrome layer is overetched beyond endpoint to clear residual 24 [0058] chrome from all open regions. Generally, the overetch step is an extension of the chrome 25 etch process described above. Longer overetch steps result in higher mean-to-target 26 deviations. Chrome spot defect densities can be affected by the length of overetch, with 27 28 lower defect densities for longer overetch processes.

[0059] After completion of the chrome layer etch, a strip and clean process is typically performed to remove any residual contaminants from the surface of the chrome layer. The strip process may be performed by heating sulfur peroxide to about 75°C and applying the heated sulfur peroxide over the surface of the substrate plate. After treatment with sulfuric peroxide, the substrate plate is typically rinsed with CO<sub>2</sub>-reionized or CO<sub>2</sub>-sparged deionized water. After strip, the substrate plate is typically subjected to an acid clean using an industry standard 70: 30 H<sub>2</sub>SO<sub>4</sub>/H<sub>2</sub>O<sub>2</sub> solution, followed by another deionized water rinse. For example, the strip step may be performed on a Steag ASC 500 wet chemical processing station, available from STEAG-HAMMATECH® (Santa Clara, CA).

[0060] The above described preferred embodiments are not intended to limit the scope of the present invention, as one skilled in the art can, in view of the present disclosure, expand such embodiments to correspond with the subject matter of the invention claimed below.

U.S. Express Ma. Jo.: ER452506884US

[0061]

#### **CLAIMS**

We claim:

1	1. In a method of patterning a layer of photoresist which has been applied over a		
2	photomask substrate and exposed to imaging radiation, the improvement comprising		
3	exposing said imaged photoresist to a vacuum for a period of time sufficient to allow pattern		
4	critical dimensions to equilibrate across said photoresist, at a process chamber pressure		
5	ranging from about 5 x $10^{-6}$ mTorr to about 5 mTorr.		
1.	2. A method in accordance with Claim 1, wherein exposure of said imaged		

- photoresist to said vacuum is performed at a substrate temperature within the range of about 18°C to about 60°C, for a period of time within the range of about 10 minutes to about
- 4 70 hours.
- A method in accordance with Claim 2, wherein exposure of said imaged photoresist to said vacuum is performed at a substrate temperature within the range of about 18°C to about 40°C, for a period of time within the range of about 20 minutes to about 12 hours.
- 1 4. A method in accordance with Claim 1, wherein said radiation is e-beam radiation.
- 1 5. A method in accordance with Claim 1, wherein said radiation is optical radiation.
- 6. A method in accordance with Claim 1, wherein exposure of said imaged photoresist to said vacuum is performed prior to the performance of a post-exposure bake process.

2

3

4

5

6

7

1

2

3

5

6

7

8

1	7. A method in accordance with Claim 1, wherein said exposure of said imaged
2	photoresist to said vacuum is performed prior to development of said photoresist to create
3	a pattern having openings through said photoresist layer thickness.

- 8. In a method of patterning a layer of photoresist which has been applied over a photomask substrate, exposed to imaging radiation, and developed to create a pattern having openings through said photoresist layer thickness, the improvement comprising exposing said developed photoresist to a vacuum at a substrate temperature within the range of about 20 °C to about 60 °C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5 x 10-6 mTorr to about 5 mTorr.
- 9. A method of patterning a layer of photoresist which has been applied over a photomask substrate, comprising:
  - a) post-apply baking said photoresist;
  - b) exposing said photoresist to imaging radiation,
  - c) exposing said imaged photoresist to a vacuum for a period of time sufficient to allow pattern critical dimensions to equilibrate across said photoresist, at a process chamber pressure ranging from about 5 x 10<sup>-6</sup> mTorr to about 5 mTorr;
    - d) post-exposure baking said imaged photoresist; and
- 9 e) developing said imaged photoresist to create a pattern having openings 10 through said photoresist layer thickness.
- 1 10. A method in accordance with Claim 9, wherein exposure of said imaged 2 photoresist to said vacuum is performed at a substrate temperature within the range of about 3 18°C to about 60°C, for a period of time within the range of about 10 minutes to about 4 70 hours.

1	11.	A method in accordance with Claim 10, wherein exposure of said imaged					
2	photoresist to said vacuum is performed at a substrate temperature within the range of about						
3	18°C to	18°C to about 40°C, for a period of time within the range of about 20 minutes to about					
4	12 hours	12 hours.					
1	12.	A method in accordance with Claim 9, wherein said radiation is e-beam radiation.					
		:					
1	13.	A method in accordance with Claim 9, wherein said radiation is optical radiation.					
	•						
1	14.	A method in accordance with Clairn 9, wherein said method further includes the					
2	following step:						
3 -		f) exposing said developed photoresist to a vacuum at a substrate					
4 .	temperature within the range of about 20°C to about 60°C for a period of time within the						
5	range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from						
6	about 5 x 10 <sup>-6</sup> mTorr to about 5 mTorr.						
1	15.	A method of patterning a layer of photoresist which has been applied over a					
2	photom	ask substrate, comprising:					
3		a) post-apply baking said photoresist;					
4		b) exposing said photoresist to imaging radiation;					
5	·	c) post-exposure baking said imaged photoresist;					
6		d) developing said imaged photoresist to create a pattern having openings					
7	through	said photoresist layer thickness; and					
8		e) exposing said developed photoresist to a vacuum at a substrate					
9	temperature within the range of about 20°C to about 60°C for a period of time within the						
10	range of	f about 10 minutes to about 60 minutes, at a process chamber pressure ranging from					

about 5 x  $10^{-6}$  mTorr to about 5 mTorr.

11

- 1 16. A method in accordance with Claim 15, wherein said imaging radiation is e-beam
- 2 radiation.
- 1 17. A method in accordance with Claim 15, wherein said imaging radiation is optical
- 2 radiation.

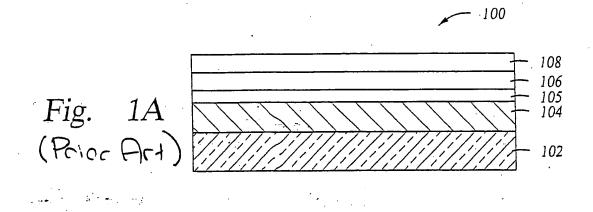
#### [0062]

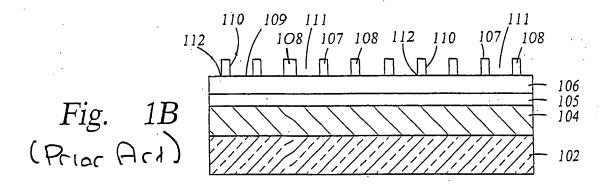
9 .

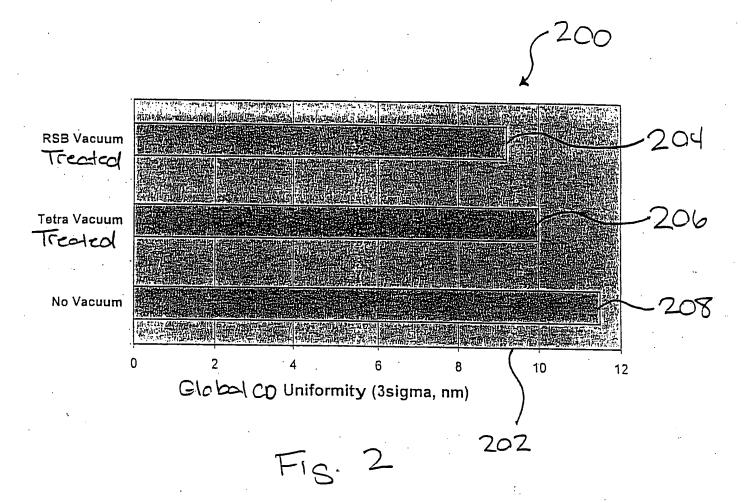
#### ABSTRACT OF THE DISCLOSURE

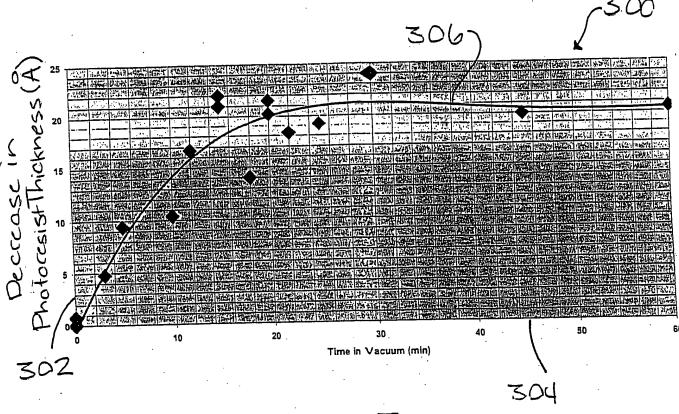
[0063] We have discovered that exposure of a photoresist on a photomask substrate to a vacuum after the photoresist has been exposed to imaging radiation results in improved critical dimension uniformity of the developed photoresist. Exposure of the imaged photoresist to vacuum is performed for a period of time sufficient to allow pattern critical dimensions to reach equilibrium across the photoresist. The vacuum treatment process of the invention is typically performed prior to the performance of a post-exposure bake process and prior to development of the photoresist. We have also discovered that exposure of a photoresist on a photomask substrate to a vacuum after the photoresist has been developed results in an improvement in the line edge roughness of pattern openings that have been formed through the photoresist layer thickness.





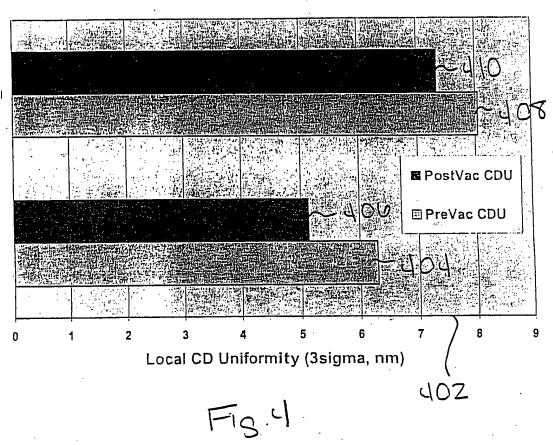


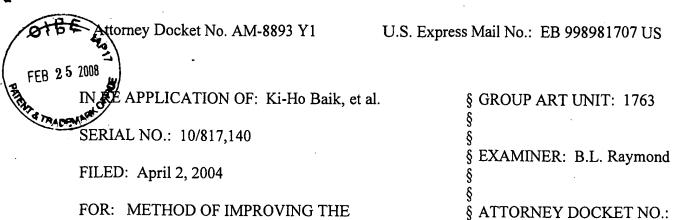




Fis. 3







UNIFORMITY OF A PATTERNED RESIST ON A

**PHOTOMASK** 

## EXHIBIT "D"

AM-8893 Y1

## STATEMENT FROM U.S. POST OFFICE DELIVERY PERSON

UNITED STATES
UNITED STATES POSTAL SERVICE

# Dear Postal Customer:

We received the enclosed piece of mail as undeliverable and unreturnable for one or more of the following reasons. Your letter was opened to determine the address for returning the item.

Insufficient postage and/or	OR	Illegible delivery or return address	Insufficient address
Undeliverable as Addressed No Return Address		Mail refused by addressee	Identical delivery, return address or organization with no postage
		_Invalid postage: stamps are void when covered, coated or reused	Contents inserted improperly address not visible

**USPS Mail Recovery Center** 443 Fillmore Ave E St Paul MN 55107-9607

Please use a return address on all mail

www.usps.com

FOR PICKUP OR TRACKING CALL 1-800-222-1811

